# Numerical Simulation of Projectile/Armor Interaction Using CartaBlanca

Xia Ma, Duan Z. Zhang, Paul T. Giguere, Qisu Zou, T-3

Accurate modeling and simulation of material strength and motion under ballistic or impact-loading conditions is a significant challenge and is of profound interest in this Laboratory. Recently, after significant improvements of the particle-in-cell (PIC) method and advancements of multimaterial interaction theory, we have developed a numerical method for such calculations.

On the modeling front, we developed a continuous multiphase flow or multimaterial deformation theory, and introduced a multipressure model. In this model each of the interacting materials possesses its own stress and pressure fields. A distinct advantage of this model is its ability to describe tension failure of a solid in coexistence with gas. In this model, the gas can remain under compression while allowing solid material to break under tension.

On the numerical front, a new algorithm is introduced to accurately satisfy the continuity constraint in a material point method (MPM) used for calculating multimaterial deformations. The MPM is an advanced version of PIC. Since its invention in the 1960s, the PIC method has been used in various problems, but the accuracy of satisfying the continuity constraint for multimaterials has limited its application. With the new algorithm, the continuity constraint is satisfied to a higher order of accuracy; therefore the MPM can be used to accurately calculate large deformations involving multimaterials and to avoid the numerical diffusion and mesh tangling issues associated with conventional Eulerian and Lagrangian methods.

Both the new theory and the new numerical method have found broad applications ranging from new design concepts of nuclear reactors, to mitigation of brain injuries due to improvised explosive device (IED) explosion, near-earth asteroid deflection, and the safety of liquid rocket fuels.

The figures shown in this article are from an armor-piercing calculation in which a cylindrical projectile is shot into high-hard armor steel. Figure 1 shows stress evolution in the steel during the penetration process. Our numerical results are compared with experimental data in Fig. 2.

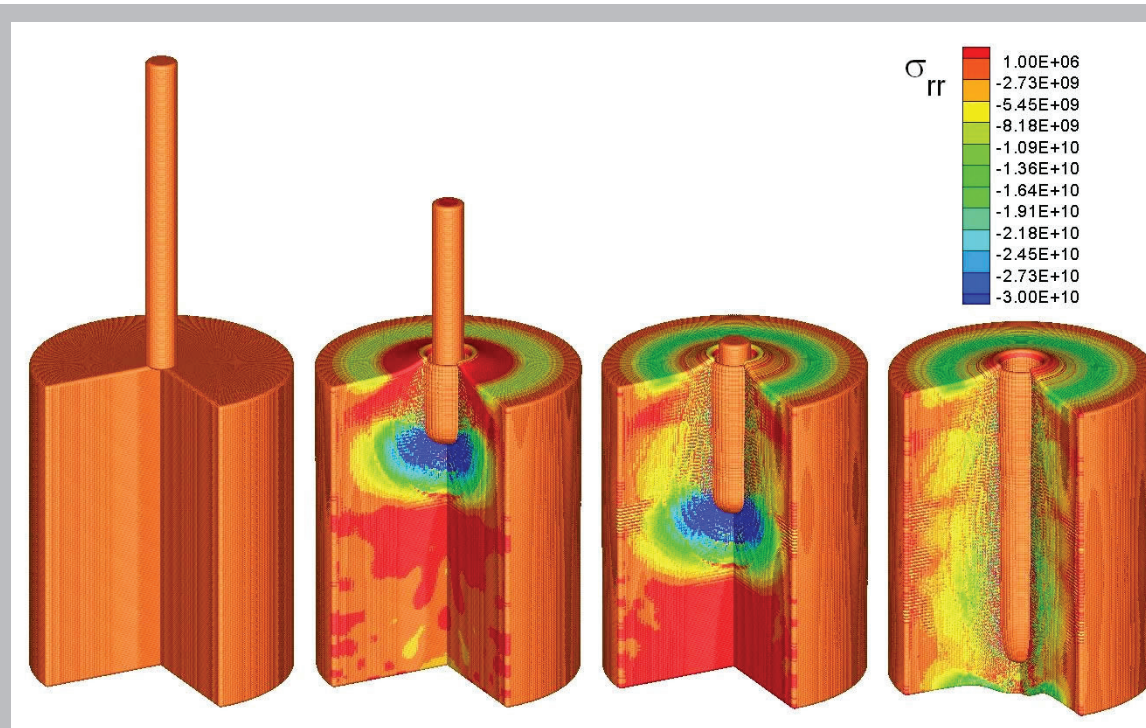


*Fig. 1. A tungsten rod penetrating a steel block (colors represent stress distribution).*

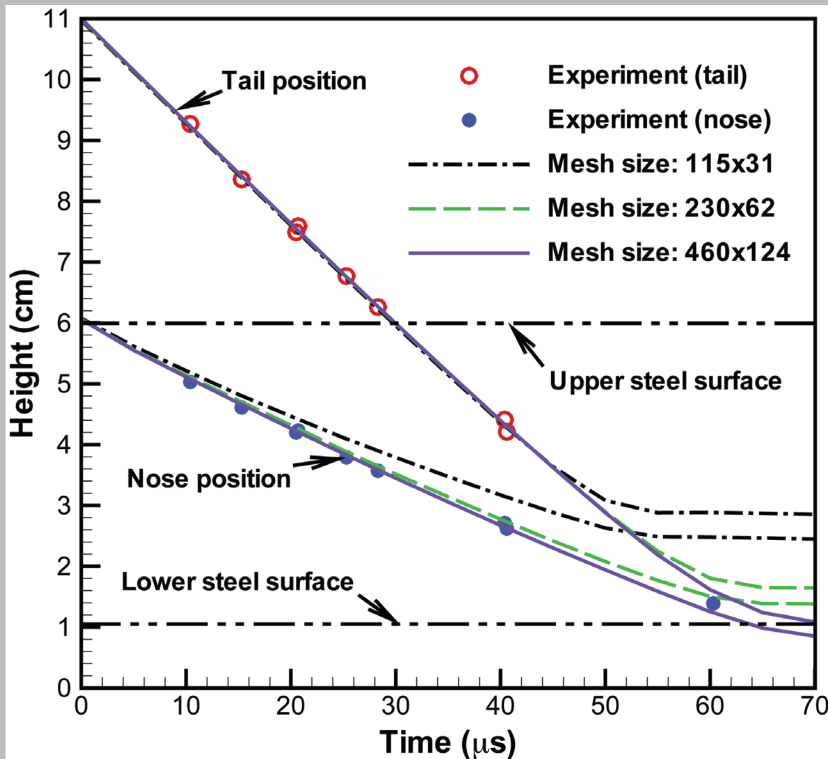


*Fig. 2. Comparison of numerical results with experimental data.*

**For further information contact Xia Ma at xia@lanl.gov.**

**Funding Acknowledgments**
- Department of Energy, Global Nuclear Energy Partnership